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FLOODING RISKS AND HOUSING MARKETS: A SPATIAL HEDONIC ANALYSIS FOR LA PLATA CITY

Rabassa Mariano
Zoloa Juan
Epele Nicolá

Flooding risks and housing markets: a spatial hedonic analysis for La Plata City

Preliminary Draft*

Mariano Rabassa† Juan Ignacio Zoloa‡ Nicolas Epele§

Abstract

This study examines the impact of flood-hazards on residential land prices. The study use data from undeveloped parcels of land for sale during 2004 in La Plata, Argentina. A spatial hedonic model is developed to provide efficient estimates of the marginal effect of being located on a food-prone area on property prices. Results suggest significant property price discounting. The price of a parcel of land situated within a food-prone area is about 17.3 percent lower than an equivalent property outside those areas.

Introduction

As population densities in urban areas increase, the potential losses due to flooding events can have major economic impacts (Guofang et al., 2003; Hallegatte and Corfee-Morlot, 2011). Climate change compounds the risks from flooding, as sea levels rise and extreme events occur more frequently. Proactive adaptation can help to manage urban flooding risks (Dawson et al., 2011). However, proactive adaptation requires buy-in from the community.

How willing residents might be to engage in longer-term adaptations to current and future climate risks will depend on the implications for their net wealth. We use a spatial hedonic model to uncover the flooding price signal for residential land property. Hedonic modeling has an extensive history in urban studies. We extend this research by exploring flood-related price discounting. Price discounting

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†Universidad Catolica Argentina
Mail: marianorabassa@gmail.com
‡Universidad Nacional de La Plata
Mail: juanignaciozoloa@gmail.com
§Universidad Nacional de La Plata
Mail: nicolasepele@gmail.com

as a consequence of flooding has only been studied using hedonic analysis of market prices on a small number of occasions, including studies in the US (Bartosova et al., 1999; Bin and Kruse, 2006; Bin et al., 2008; Donnelly, 1989; Park and Miller, 1982; Shultz and Fridgen, 2001; Thompson and Stoevener, 1983;), Europe (Daniel et al. 2009) and Japan (Guofang et al., 2003). Most of these studies attempt to estimate the effect of flooding on residential or commercial prices in the few years immediately following a major event. Internationally, previous studies generally found that location within a floodplain significantly reduces the property values by 5–10 per cent relative to similar flood-secure housing in the same area (Bartosova et al., 1999; Bin and Kruse, 2006; Donnelly, 1989; Guofang et al., 2003; Speyrer and Ragas, 1991; Thompson and Stoevener, 1983). Other studies found small or no responses (Shaefer, 1990).

The real estate markets have a particular characteristic that makes them interesting. In them, differentiated products are traded in very well integrated markets. Those are compound goods whose consumer utility depends on the utility provided by each of the characteristics or attributes which are part of them.

The main idea is that these attributes are not explicitly traded in the market but they constitute a package of characteristics that are commercialized along with the property rights. The most commonly used technique to study the contributions of each of those characteristics to the price of the compound good is the econometric approach of hedonic price developed by Rosen (1974) and Sheppard (1999) which uses the attributes or characteristics of the compound good as regressors.

In real estate market, housing characteristics may not be valued equally across a given distribution of housing prices. Specifically, the marginal value of a certain housing characteristic may be different across the range of house prices. In fact, one would expect that owners of high-end houses and low-end houses give different value to each housing characteristic.

Another characteristic of this market is the existence of spatial relationships. According to Anselin (1988) there are two types of spatial interactions. The first one is the spatial dependence that emerges whenever a variable tends to assume similar values in geographically close units. Such spatial dependence is widely observed in real estate markets, for example: expensive houses tend to be close to other expensive houses. This spatial price correlation could be the response to herd behavior, where the expectations of the future costs are formed on the basis of the sale values of neighboring units. The amenities also contribute to the spatial correlation, since the consumers receive positive utility from living near nicer houses. The high price of a property for sale pushes up the price of all the neighborhood´s houses. This captures the intuitive idea that a house surrounded by expensive houses is worth more than a house surrounded by inexpensive houses. Then, the neighboring house prices act as an explanatory variable of a house price at a particular location.

The second one is spatial heterogeneity, which is related to the lack of stability over the space in connection with the behavior of the relationships under study. More precisely, this implies that the functional forms and the parameters are not homogeneous and vary according to the location.

This type of relationships present methodological challenges in the econometric estimation. However, recent statistical and software developments have allowed to model the spatial dimension of the urban processes better. The development of the geographic information systems (GIS) has allowed to plot the information into maps, simplifying the analysis and communication. Nevertheless, the statistical methods of the spatial analysis were less used, partly due to the mathematical and computer problems that those methods implied, and to the little georeferenced information available. In this paper, we incorporate the spatial phenomena in the study of the impact of flood-hazard zone location on residential land prices.

The paper is organized as follows: in the first section we describe the theoretical framework and in the second the spatial framework. The third section presents the data used. In the fourth section we perform the empirical estimation and finally we present the concluding remarks.

1 Theoretical framework

The theory of land value establishes that the land price is the result of certain factors (topography, proximity to economic centers, quality of the surroundings areas, etc.) which could be considered as individual attributes of a specific lot. The market price of a specific lot will depend on two different factors: intrinsic factors and extrinsic factors.

The former are the attributes that the lot possesses and which are not related to the zone in which it is located, such as block location, surface dimensions, land quality, zoning codes, etc. The latter refer to factors that add value to the lot and that are characteristic of the zone. Among them, we can find the topography of the place, the quality of public services and the infrastructure of the zone (proximity to avenues, hospitals, schools, etc.).

According to this theory, the market value of each lot will depend on a set of attributes whose most striking characteristic is that those attributes are not traded individually in a single market, but they are jointly commercialized in a unique market as a single good.

Formally:

$$P_i = f(A_1, A_2, ...A_n) \tag{1}$$

(1)

Where P_i is the price of the lot i and A_i are the magnitudes of the n attributes of the lot. The theoretical foundations of this procedure to obtain the determinants of market prices are in Rosen (1974). Taking as a basis the hedonic hypothesis that the goods are valued by the utility offered by their attributes or characteristics, Rosen (1974) develops a differentiated product model in which the implicit prices of the attributes are revealed by the economic agents from the observed prices of differentiated products and the amounts and qualities of the attributes associated to them. The estimated coefficients from hedonic regressions must be interpreted, generally, as implicit marginal prices of the attributes that can be used to estimate demand functions.

1.1 Spatial analysis

One of the most usual techniques to determine which are the most relevant attributes and the relative importance of each coefficient is the regression analysis of cross section. Nonetheless, the omission of space interaction could bias the results and invalidate the usual tests of significance. Developments of spatial econometrics have addressed these issues and provided various remedies. Anselin (1988) and LeSage and Pace (2009) offer a wide coverage of these methods. As it was mentioned before, there are two kinds of spatial interaction: spatial dependence and spatial heterogeneity, which are described as follows.

1.1.1 Spatial dependence or spatial autocorrelation

The spatial dependence or autocorrelation is a property of spatial data that exists when a variable tends to assume similar values in geographically close units. Such spatial dependence is widely observed in real estate markets; expensive houses tend to be close to other expensive houses. Thus, we can see that there is a positive spatial autocorrelation when high or low values of a specific variable form a cluster in the space, and there will be negative spatial autocorrelation when the neighborhood of certain geographic areas presents diverse values.

The spatial dependence is in the error term and violates the classical assumption of Ordinary Least Squares of no serial correlation between errors. If that correlation is ignored, the estimated parameters will be inefficient, the t & F statistics will be biased and the goodness of fit will be misleading. Anselin (1992). On the other hand, spatial clusters violate the independence assumption and generate problems in the correct estimation of Least Squares Regression.

At first sight, spatial dependence may seem similar to the most familiar time-wise dependence encountered in the econometric test for serial correlation, in distributed lag models and other time series analyses. However, the multidirectional nature of spatial dependence, which opposes to a clear one-directional situation in time, precludes the application of many simplifying results and necessitates the use of a different methodological framework Anselin (1992).

The space organization and the spatial structure of the phenomena tend to generate complex patterns of interaction and dependence. These relationships can express either processes of "contagion" or reciprocal influence between the observation units, or can be the result of economic, social or political forces that tend to group populations with similar characteristics in certain areas (urban segregation).

1.1.2 Spatial heterogeneity

Spatial heterogeneity is related to the lack of stability over the space of the behavior of the relationships under study. More precisely, this implies that the functional forms and the parameters are not homogeneous and vary according to the location.

Spatial heterogeneity indicates the presence of systematic differences in the occurrence of a phenomenon in different geographical areas. Thus, this could have different distributions over the space sub-group of the data or, simply to change with the location of the units Anselin (1992). For example, heterogeneity can be observed if in the South zone the levels of prices are different from those of the North zone or if the explanatory variables have a different effect on certain regions.

In most of the empirical works in which the data come from regional aggregates, spatial heterogeneity is an important problem. In this work we have specific space units, and this is the reason why we thought that it is not an important problem.

2 Methodology

Lattice models are perhaps the most widespread used in the hedonic literature and will be the focus of this paper[1] . The spatial econometric literature suggests two main spatial models that can be specified: the spatial lag model (LAG) and the spatial error model (ERR).

The specification generally used to model the diverse space processes is as follows:

$$P = \rho W_1 P + X\beta + \varepsilon \tag{2}$$

Where:

$$\varepsilon = \lambda W_2 + \mu \tag{3}$$

where $\mu \sim N(0, \Omega)$, and the diagonal elements of the error covariance matrix Ω are with $\Omega_{ij} = h_i(z, \alpha)$. In this specification P is an n by 1 vector of observations on the dependent variables, X is an N by

[1] As it name suggests these models are defined for lattice data which is data associated with some division of an irregular lattice. This means that the observations can be considered as spatial objects (see Besag 1974, for some examples of different types of lattice data)

k matrix of observations on explanatory variables, β is a k by 1 vector of parameters associated with exogenous (not lagged dependent) independent variables, ρ is the coefficient of the spatially lagged dependent variable and λ is the coefficient in the spatial autoregressive structure for the disturbance ε. The disturbance μ is taken to be normally distributed with a general diagonal covariance matrix Ω. The diagonal elements allow for heteroscedasticity as a function of $T+1$ exogenous variable z, which includes a constant term. The T parameters α are associated with the non constant terms, such that, for $\alpha = 1$ it follows that:

$h = \sigma^2$

The two n by n matrices, W_1 y W_2, are spatial weight matrices, respectively associated with a spatial autoregressive process in the dependent variable and in the disturbance term Anselin (1988). The literature has documented several types of specifications that can be broadly classified into contiguity and distance-based matrices. The matrices are often row-standardized to constrain the sum of elements of each row to be equal to 1, so that the above model conceptually means that the price of each property is affected by a form of weighted average prices of nearby properties.

The particular models from the general structure are the following.

Model 1, with $\rho = 0, \lambda = 0, \alpha = 0$

$$P = X\beta + \varepsilon \tag{4}$$

The classic linear regression model, with no spatial effects

Model 2, with $\lambda = 0, \alpha = 0$

$$P = X\beta + \rho W_1 + \varepsilon \tag{5}$$

The mixed regressive-spatial autoregressive model, which includes common factor specification with WX included in the explanatory variables (Spatial Lag model).

Model 3, with $\rho = 0, \alpha = 0$

$$P = X\beta + (I - \lambda W_2)^{-1}\mu \tag{6}$$

The linear regression model, with spatial autoregressive disturbance (spatial Error).

Model 4, with $\alpha = 0$, we obtain:

$$y = X\beta + \rho W_1 y + (I - \lambda W_2)^{-1}\mu \tag{7}$$

This corresponds to the mixed regressive-spatial auto-regressive model, with a spatial autoregressive disturbance.

If the above models correctly specify the data generation process, then OLS is inappropriate for the estimation. First, the spatial autocorrelation is in the error terms and violates the classical linear regression's assumption of no serial correlation in the disturbances. The presence of autocorrelation cause OLS estimators to be inefficient and their variances biased.

I assess the extent to which the selection of a particular method affects the parameter estimates in the hedonic function and the derived economic valuation of willingness to pay to avoid flood risk. Specifically, I compare non-spatial to spatial hedonic specifications.

I first obtain ordinary least squares (OLS) estimates for the hedonic model and assess the presence of spatial autocorrelation using the Lagrange Multiplier test statistics for error and lag dependence (Anselin (1988)), as well as their robust forms[2]. The results in table 2 consistently show very strong evidence of positive spatial autocorrelation, with an edge in favor of the spatial lag alternative. To model the structure of the spatially-lagged housing prices, we construct a spatial weight matrix using the distance decay matrix which assigns nearby housing units a higher weight than those that are further away.

One final methodological note pertains to the assessment of model fit. In spatial models, the use of the standard R^2 measure can be misleading since it stops having a direct linkage with the test of joint significance of the estimated (Test - F). Specifically, given that the estimation is based on maximum likelihood, the residues of the estimated model do not have zero mean and the standard decomposition of the observed variability in explained variability and residual variability is not maintained. There are several alternatives pseudo R^2 that mimic certain aspects of the traditional R^2.

- Squared correlation: this is pseudo R^2 statistic equal to the squared correlation between the predicted and the observed values of the dependent variable. It provides a linear association measure that takes values between 0 and 1. This measure is not related to the variance decomposition.

- Variance ratio: It is another pseudo R^2. It is based on the predicted values and the residuals. (Buse 1973,1979). This is a pseudo R^2 statistic equal to $V(\hat{Y})/V(Y)$where $V\left(\hat{Y}\right)$ denotes the variance of the predicted values of the dependent variable, and $V\left(Y\right)$ denotes the variance of the observed values of the dependent variable (Anselin, 1992).

In order to provide for an informal comparison of the fit of the various specifications, we report the pseudo R^2 measures.

[2]See Anselin (2001a), for an extensive review of statistical issues.

3 Data

In this paper, we use data from La Plata. The city is the capital of the Province of Buenos Aires, Argentina and according to the 2010 Census, it has a population of 642,783 inhabitant. La Plata is a planned city; a urban planning paradigm of the late 19th century. The trace of the city, designed by architect Pedro Benoit, is characterized by a strict grid, with important avenues and diagonals, occupying an area of 893 km. The city is located in the northeastern province of Buenos Aires, limiting to the northeast with the towns of Ensenada and Berisso, to the northwest with Berazategui and Florencio Varela, to the southwest, with San Vicente and Coronel Brandsen, and to the southeast with the small town of Magdalena. The metropolitan area of La Plata includes the towns of Tolosa, Ringuelet, Manuel B. Gonnet, City Bell, Villa Elisa, Melchor Romero, Abasto, Gorina, Jose Hernandez, Angel Etcheverry, Arturo Segui, Los Hornos, Lisandro Olmos, Villa Elvira, and Altos de San Lorenzo, all of them with community centers that operate as local municipal delegations. The city is fairly humid, owing to its coastal location and the average humidity is greater than 75% in each month. La Plata usually receives 1,092 millimeters of precipitation a year, with winters being the drier months and summer the wetter months.

The data was gathered by consulting undeveloped parcels of land for sale advertised by real estate agencies [3]. These agencies publish information referring to the location of the plots, the asking price, the dimension of the parcel, the availability of public services in the zone such as electricity and municipal water supply, among other characteristics. The flood risk data comes from a study produced by the Instituto de Geomorfologia y Suelos (IGyS) of the Universidad Nacional de La Plata at the beginning of the 2000s, which was published by (Consejo Federal de Inversiones) in 2006. This report analyzes the flood-prone areas of La Plata City based on the geomorphology of the terrain and the runoffs. It represents the confluence of flooding problems, flooding and rising water table. From the physical standpoint, flood-prone areas are those areas most likely to be affected by rainfall and flooding of water bodies, which in turn influence the relative position of the water table, reducing underground storage capacity. The flood plains of rivers and streams, and ponds are naturally more risky.

The data used in this paper include 679 parcels of land offered in the housing market for sale[4] . In order to link plots to flooding risks we had to geo-referenced each one; this process was carried out manually. We then gathered the flooding risk map and the geographic locating of each observation,

[3] www.sioc.com, www.badpro.com, y www.veralotes.com.ar.

[4] The lots located in gated communities (clubs de campo, barrios privados, etc.) were not considered in this work, because other factors are involved in the determination of their price, such as the services that are lent, security, sports and the location of the lot within the estate. The data had to be consistent, that is to say the surface data did not have to differ considerably with the resulting data of multiplying the value of width and length. Lands located in zones not legally allowed for construction were not considered.

i.e. parcel of land, in the digital map with the help of GIS software. This procedure allowed us to calculate distances between the plots and several attributes, such as the distance to the city center. Before analyzing the data, it is necessary to clarify that it was not possible to access data on real estate transactions and for this reason we rely on asking prices. Although they are not the equilibrium values, asking prices are established mostly by experienced appraisers which allow us to assume that they are not very different from the equilibrium values[5]. Moreover, the relatively high market activity during 2004 suggests that sellers very often sold for their asking prices, implying that these prices should also be closer to transaction values.

Figure 1:

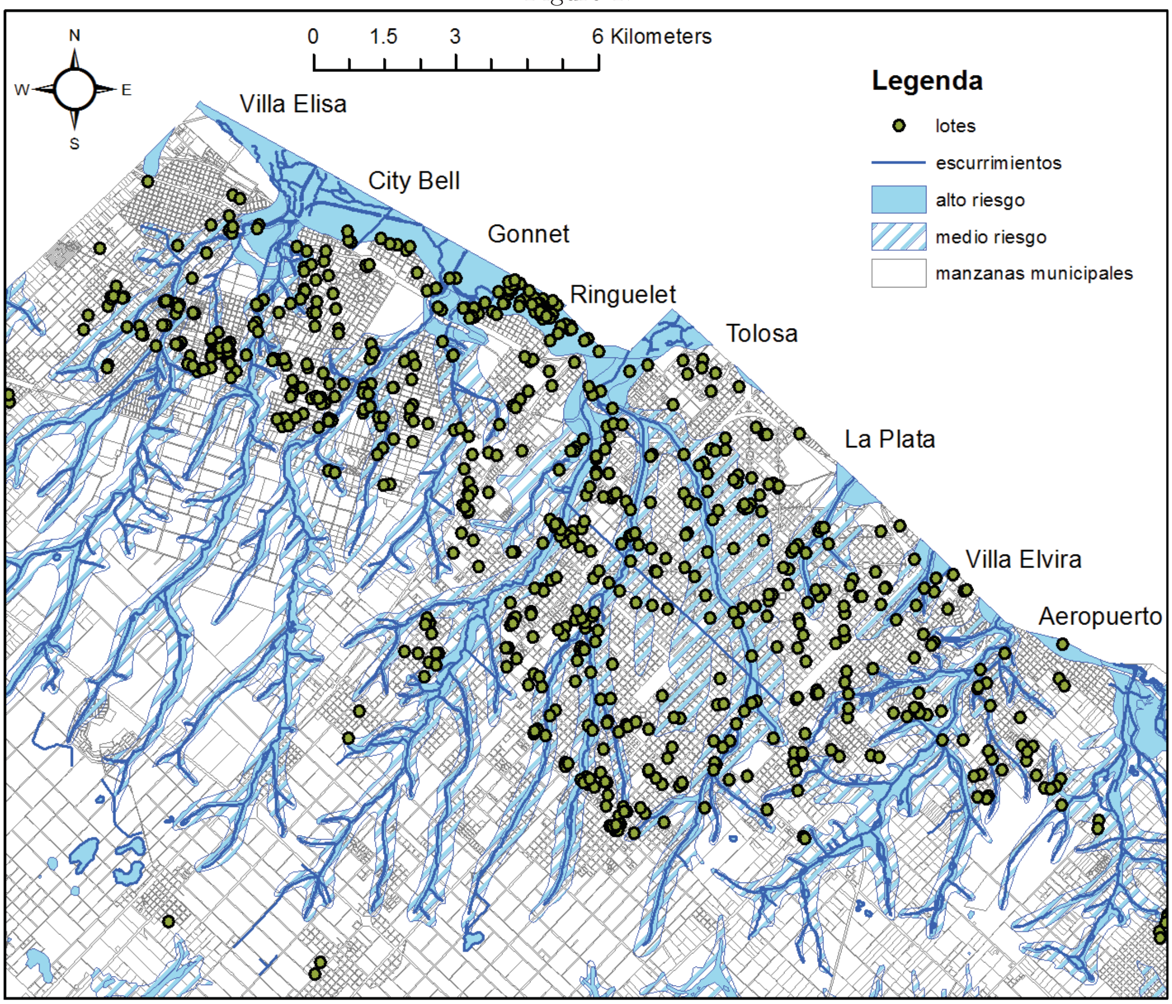


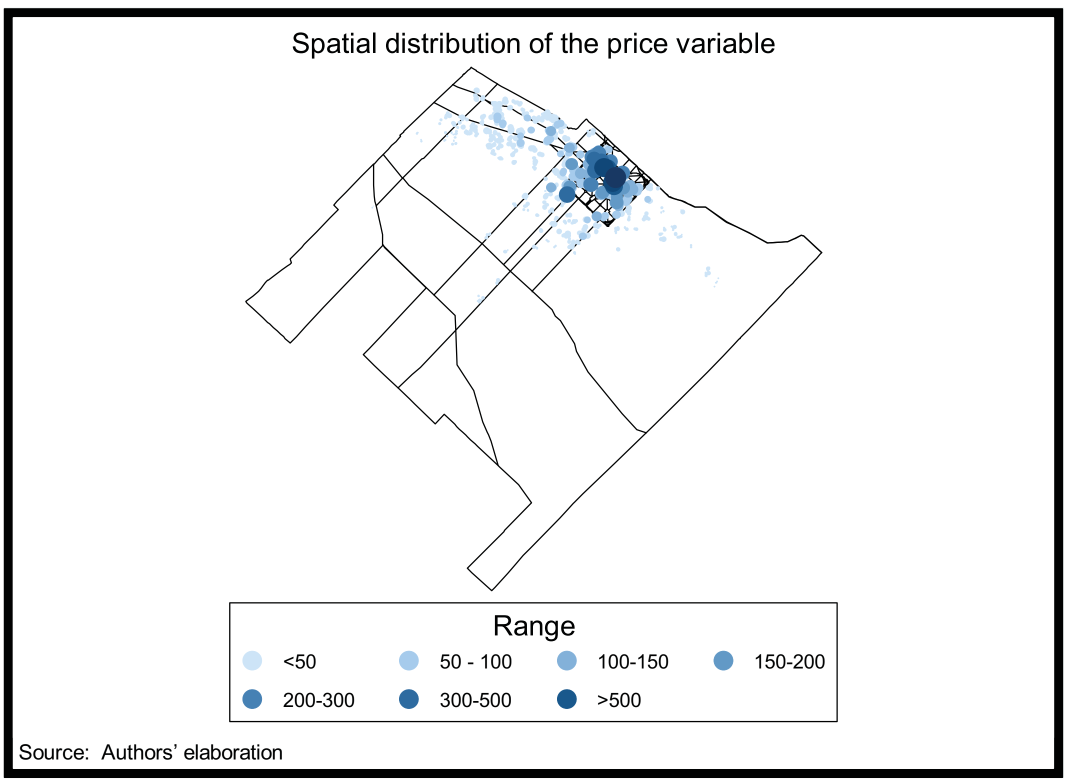
Figure 1 shows the lots that make up our sample together with the runoff and flood-prone areas of the party. It can be seen to the northwest the river basin Carnival-Martin, which crosses the towns of Arturo Segui, Arana and Villa Elisa. The next basin toward the city of La Plata is composed by

[5]In Argentina, actual transaction values are seldom recorded with accuracy, usually underreported, in order to evade taxes. In this context, asking prices are more likely to reflectactual transactions rather than the reported values in sales receipts.

the streams Rodriguez and Don Carlos, which pass through the towns of Gorina, Hernandez, Las Quintas y City Bell. The third basin to the east is formed by Gato stream, and its tributaries Perez and Regiment creeks. These streams cross the towns of Gonnet, Villa Castels, Ringuelet, Tolosa, San Carlos, Melchor Romero, Olmos, Gambier, Etcheverry, Los hornos and east portion of La Plata. In the northeastern part of La Plata is located the rather small Zoo basin. Finally, the eastern part of the city is on Maldonado Creek watershed,which includes the neighborhoods of Monasterio, Villa Elvira, Jardin Airport, Cemetery, San Lorenzoand Villa Garibaldi.

The dark blue lines on the map show the city's runoff. The solid light blue areas are known as floodplains, which are subject to a high flood risk. Usually includes the banks of streams, buckets and ditches, mud plains, canyonsand ancient inner estuary. The flood risk variable in our study takes value of 1 if the plot is located in these geographical units as classified by the IGyS study. The risk of flooding of these areas is high, with a recurrence of a flooding every 5 to 10 years. About 21 percent of the plots that make up our sample are located in these high risk areas.

Figure 2:



The blue hatched regions surrounding the high-risk areas are the medium risk areas which include the slopes that converge to the streams. Around 27 percent of the sample batches are located in areas of medium risk. The rest of the plots, 52 percent, faces a very low risk of flooding. The spatial distribution of the parcels is shown in Figure 2. The size of each point is proportional to the value of the square meter of each plot. As it can be seen in the Figure 2, the higher values are in the city center and near the most important avenues.

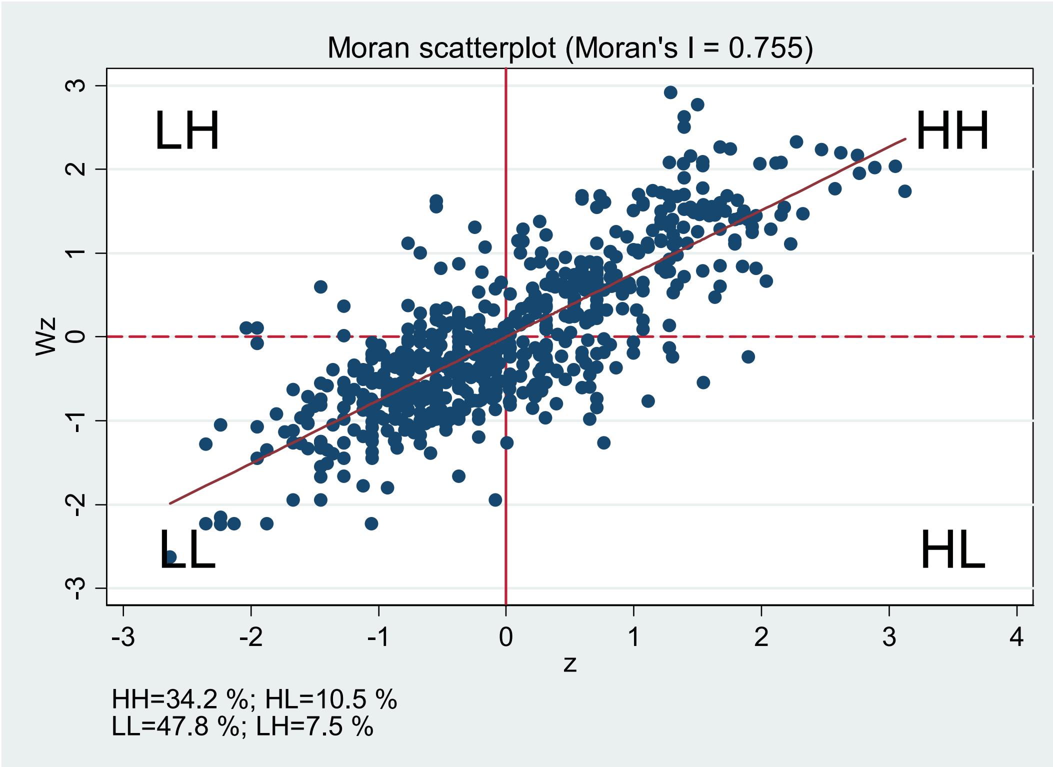
In Table 1 it can be seen that the average price per square meter is 163 argentine pesos with a standard deviation around 208 pesos. On average plots are 15 meters width by 39 meters in length. While the width ranges from 8 to 53 meters, the length ranges from 17 to 111 meters. Nearly 72% of the parcels have gas service and almost half of them are located in a paved street or road. A bit more than 50% have access to sewer and more than 75% have access to the running water system. The average distance to the center is 7 kilometers but it ranges from 1 to 16 kilometers.

The Total Factor Occupancy (FOT) is the relationship between the maximum surface that can be built and the surface of the plot. A FOT of 2.5 means that the owner can build 2.5 times the total surface of the plot. For example, in a plot of 100 m2 it can built up to 250 square meters of covered living space. The mean value of FOT is 1.07 implying that on average, in that land, it can be built 107% of the total surface in several floors. Its value ranges from 60% to 300%, depending on the zone. Figure 4 displays the spatial distribution of the FOT coefficient.

In order to check for differences between flood-prone and risk-free areas we present several mean-difference tests. We found that, on average, the total surface of plots located in areas with higher flooding risks are also higher, have lower occupancy factor. In addition, these plots have lower access to municipal water provision and are located on unpaved blocks.

One of the most usual method to detect spatial patterns is by Moran's I statistic. The index is analogous to the conventional correlation coefficient, and its value also ranges from 1 meaning strong positive spatial autocorrelation to -1 strong negative spatial autocorrelation. This relationship can be observed in Figure 3. It is important to remark that Moran's I statistic is significant at 1% confidence level, indicating that we can reject the null hypothesis of non-spatial autocorrelation between the observed values.

Figure 3:



where z is the normalized price and is the normalized price of its neighbors.

The value of Moran's statistic of log prices per square meter displays a high value of 0,792, which shows the existence of a positive and strong space correlation between the prices of the lots, which means that the expensive lands tend to be placed near the lots of greater value and the lands of smaller value tend to be located near the cheapest ones.

Anselin (2005) proposes several tests that allow to detect the kind of spatial relationship present in the data. Such tests were based on the principle of Lagrange multiplier and allow to select the best model to use.

Table 1: Descriptive statistics

Variable	Without flood risk	With flood risk	Total	Difference
Price	81,610	83,364	81,990	1753.4
	[107584.6]	[111981]	[108470.1]	[10114]
Price per squared feet	170.3	139.0	163.5	-31.2
	[221.98]	[145.2]	[208.08]	[19.37]
Total surface	570.7	704.9	599.7	-0.2***
	[487.87]	[691.09]	[540.67]	[0.065]
Fot	1.2	1.0	1.1	3.4***
	[0.71]	[0.63]	[0.7]	[0.809]
Length	13.8	17.2	14.5	-0.6
	[7.54]	[11.94]	[8.79]	[1.55]
Width	39.4	38.8	39.3	134.24***
	[17.06]	[14.98]	[16.63]	[50.15]
Gas	72%	72%	72%	0.00
	[0.45]	[0.45]	[0.45]	[0.042]
Water	78%	71%	76%	-0.07*
	[0.41]	[0.46]	[0.42]	[0.0395]
Pavement	54%	37%	50%	-0.2***
	[0.5]	[0.48]	[0.5]	[0.046]
Sewer	54%	51%	53%	-0.03
	[0.5]	[0.5]	[0.5]	[0.047]
Centenario	1%	3%	2%	0.01
	[0.11]	[0.16]	[0.13]	[0.012]
Belgrano	1%	1%	1%	0.00
	[0.07]	[0.08]	[0.08]	[0.007]
Distance to CBD	7.1	7.1	7.1	0.04
	[3.87]	[3.03]	[3.7]	[0.345]
Observations	532.0	147.0	679.0	

Distances reported in kilometers
Standard errors in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

The results obtained for lands in La Plata are shown in Table 2. As it can be observed all the tests are significant and they allows to reject the null hypothesis of spatial non autocorrelation. Following the decision rule proposed by Anselin (2005), which establishes that we must select the model with the greatest Lagrangian multiplier value, the model that better describes the space interrelations of the data is the Spatial lag.

Table 2: Spatial Diagnostics

Model	Statistic	
	Lagrange multiplier	Robust Lagrange multiplier
Spatial error	66.617***	75.06***
Spatial lag	8.883***	17.326***

* significant at 10%; ** significant at 5%; *** significant at 1%

These results show that the main problem in the estimation is the spatial dependence. It appears where a variable tends to assume similar values in geographically close units. The presence of spatial clusters violates the assumption of the independence of the observations and generates problems in the correct estimation of the models of ordinary least squares. If that correlation is ignored, the estimated parameters will be inefficient, the t & f statistics will be biased and the goodness of fit will be misleading.

4 Regression analyses

In real estate markets consumers must choose a complete unit, nevertheless each individual characteristic of a piece of land is valued independently. The hedonic prices approach provides a methodology to identify the implicit price structure. In the regressions carried out in this work, we use the logarithm of the total value as dependent variable, since the log model allows an easy interpretation of the regression coefficients as semi-elasticity.

We present the estimation results of the econometric models described above in Table 3. The first column report the OLS results whereas in columns 2 and 3 we show the estimated results of the Spatial Lag model. Note that, for the spatial lag model, the marginal effect of the characteristic i for all plots is given by $\beta\left[I-\rho W\right]^{-1}$ which is different from the β of a spatial error model and traditional linear hedonic model, because the spatial lag model includes the induced effects of a change in a characteristic on all the plots. The β generally underestimates the marginal effects of the lag model. The true value of β is shown in column 3 of Table 3. It was calculated following Kim et. al (2003) that shows that the "true" value of a lot attribute i is $\frac{\beta}{(1-\rho)}$ for row-standardized weights matrix if a unit change were induced at every location.

The main focus of our study is to ascertain the effect of perceived flood risk on property prices. Estimated coefficients from this model yield that there is a significant negative relationship between property prices and flood plain location. Estimated coefficients for flood risk in both models suggest that location in a flood risk zone lowers property prices compared with a property located outside the flood risk zone, ceteris paribus.

The main focus of our study is to estimate the effect of perceived flooding risks on undeveloped property prices. Results from this model suggest that there is a negative and statistically significant relationship between property prices and a flood-prone location. Estimated coefficients on flood hazards in both OLS and spatial models suggest that being located in a flood risk zone lowers property prices compared with a similar property located outside that zone.

The estimated marginal effects in the non-spatial model reveal that a flood plain property is priced 15 percent lower than an otherwise similar house located outside the flood plain. As mentioned above in presence of spatial autocorrelation, the OLS estimators are inefficient and their variances are biased. When the spatial effects are considered the marginal effect is reduce to 17.3 percent. This implies that the marginal benefit per household[6] of being located outside a flood-prone zone was, on average, $14,172.

In general, the estimated coefficients remain fairly stable across models. The estimates obtained with the Spatial lag model are slightly smaller in absolute value, but significance remain the same. We found a positive, significant, and decreasing relationship between the size measures of the plot and the price of the land, indicating that as the parcels' size length increase the price rise at a decreasing rate. The relationship with the width also positive and decreasing. As it was expected there is a positive relationship with the total occupancy factor (FOT).

The coefficient on the availability of sewer is positive and significant indicating that the possession of such services increases the value of the lot.

Connectivity is among one of the most desired attributes at the moment of choosing where to live, however living on a main road might be a source of negative externalities. The effect is therefore unknown a priori. Those plots located on Belgrano Road are not discounted relative to similar plots. In contrast, those plots located on Centenario Road have higher value. Another relevant variable is the distance to the City Business District. The relationship between the distance from a plot to the corner of 7 Avenue and 50 Street and the price of the land. The distance coefficients are is negative and significant. An additional kilometer away from the CBD represents a 13 percent reduction on the plot sale price at average distance.

Different neighborhoods have different attributes. Some of them are nicer than others, or more quite, or have different architectural style. These characteristics are unobservable to us. We include a set of dummy variables for each neighborhood which should capture these differences. These variables turned out to be highly significant, indicating that the parcels that are located in the Northwestern

[6] The mean MWTP of sample is calculated by dividing the total sample benefits by the number of observation. That is, mean MWTP per household in the sample is calculated as follows:
$MWTP = \left[\left\{\beta_{flood}\left[I - \rho W\right]^{-1} P\right\}/n\right]$,
where n is the number of observations.

zone are more expensive, followed by the downtown, then south-west area and the south-east zone. These results are in line with our expectations.

The goodness of fit is an important aspect in the econometric analysis. In spatial econometrics, it is a little more complicated due to the lack of a standard measure as the traditional R^2. Although this measure is generally reported in most of the econometric packages, its interpretation under the presence of spatial effects can be misleading, because it does not have a direct link with the test of joint significance of the estimated Test - F.

In Table 3 we also report those statistics. As it can be seen, the value of the adjusted R^2 in the OLS model is 0.78, whereas for Spatial Lag model the value of variance ratio is 0.81 and the squared correlation value is 0.81. Overall, these measures indicate a substantive fit of the model to the observed data.

Table 3: Coefficient Estimates

Variables	MCO	Lag	Marginal Effects
Flood risk	-0.150***	-0.121***	-0.173***
Fot	0.413***	0.341***	0.487***
Length	0.091***	0.083***	0.119***
Length 2	-0.001***	-0.001***	-0.001***
Width	0.020***	0.018***	0.026***
Width 2	-0.000***	-0.000***	-0.000***
Gas	0.076**	0.066*	0.094*
Water	0.039	0.056	0.08
Pavement	0.073	0.055	0.079
Sewer	0.199***	0.185***	0.264***
Centenario	0.679***	0.534***	0.763***
Belgrano	-0.06	-0.023	-0.033
Distance to CBD	-0.215***	-0.130***	-0.186***
Distance to CBD 2	0.006***	0.003**	0.004**
Southeastern zone	-0.662***	-0.520***	-0.743***
Southwestern zone	-0.366***	-0.269***	-0.384***
Northwest zone	0.544***	0.334***	0.477***
Constant	9.530***	6.070***	8.671****
Observations	679	679	
Adj R-squared	0.78		
Rho		0.3	
Variance ratio		0.81	
Squared corr		0.81	

* significant at 10%; ** significant at 5%; *** significant at 1%

5 Policy analysis

This paper concludes with the comparison of the valuation to avoid flooding risks computed from the estimated parameters obtained by the alternative methods.

In a hedonic model, the implicit price of any characteristic maybe obtained as the derivative of the hedonic price equilibrium equation with respect to the characteristic of interest. In a non-spatial log-linear model, the marginal willingness to pay (MWTP) for any characteristics equals the estimated coefficient for that characteristic times the price (P), or

$$\widehat{MWTP}_{noise} = \frac{\partial P}{\partial noise} = \hat{\beta}_{noise}\, P \tag{8}$$

As shown in Kim et al. (2003), a spatial multiplier effect needs to be accounted for to accurately compute the MWTP in a Spatial Lag model. For a uniform change in the amenity across all observations the MWTP then follows as:

$$\widehat{MWTP}_{noise} = \frac{\partial P}{\partial noise} = \hat{\beta}_{noise}\, P \left(\frac{1}{1-\hat{\rho}}\right) \tag{9}$$

Where ρ as the estimate of the spatial autoregressive coefficient.

The distinction between (8) and (9) is important in light of the recent discussion by Small and Steimetz (2006). They consider the different interpretation of welfare effects between the direct valuation in (8) and the multiplier effect included in (9). In their view[7], the multiplier effect should only be considered as part of the welfare calculation in the case of a technological externality associated with a change in amenities. In the case of a purely pecuniary externality, the direct effect is the only correct measure of welfare change. A strong argument in favor of using a spatial lag specification (where warranted by the data) is that it allows the two effects to be considered explicitly. In Table 4 we report the MWTP to avoid flooding risks,

The marginal benefits per household[8] is about \$12,300 for the OLS hedonic models, and \$14,172 in

[7] The appropriate welfare measure depends critically on the underlying assumption about whether the spatially induced price effects change the amenity value of each location. If the spatial multiplier captures purely pecuniary externalities, then (9) overstates the benefits of a uniform quietness improvement by a factor of $\frac{1}{1-\hat{\rho}}$. In this case; simply using the OLS estimates would overstate the benefits by about the same amount. On the other hand, if the spatial multiplier captures technological externalities, then (9) provides the appropriate welfare measure and omitting the multiplier would understate the benefits of the improvement.

If reduced pollution increases my neighbors' property values, thereby increasing the value of my house, but does not further improve the amenity value of my house, then the spatial effect is pecuniary and, therefore, welfare-neutral. If, on the other hand, I derive increased utility from my neighbors' rise in property values, then the spatial effect is technological and is appropriately included in welfare analysis. In the former case, the direct coefficient on pollution produces the correct measure, whereas in the latter case the application of a "spatial multiplier" produces the correct measure.

[8] The mean MWTP of sample is calculated by dividing the total sample benefits by the number of observation. That is, mean MWTP per household in the sample is calculated as follows:
$MWTP = \left[\left\{\beta_{noise}\,[I-\rho W]^{-1}\, P\right\}/n\right]$,
where n is the number of observations.

the spatial hedonic version in 2004 argentine pesos. It is important to remember that these figures represent the capitalized value of the benefits of avoiding the risks of inundation. Note that this is a marginal measure that would not be expected to hold for a non-marginal change, as the ones we are evaluating in this paper. Such a non-marginal change would likely change each individual's willingness to pay and possibly also induce a new housing price equilibrium that would have to be calculated before benefits could be estimated.

Table 4: Marginal Willingness to pay to avoid flood risk

Variables	OLS	Spatial lag
Noise Coefficient	-0.15	-0.121
Rho		0.30
$\hat{\beta}_{noise}\left(\frac{1}{1-\hat{\rho}}\right)$	-0.15	-0.173
MWTP per Household	12,298.5	-14,172
% of housing Price	15%	17.3%

6 Conclusions

The purpose of this paper was to explore the magnitude of the implicit price of the risk of flooding in urban areas of La Plata. For this purpose we estimated spatial hedonic price models, which allow us to account for the interrelations that the data displays in space. Our results show that the price of an undeveloped parcel of land situated within a flood prone area is significantly lower than a comparable property located outside those areas. Estimated marginal effects reveal that a plot is priced 17.3 percent lower than an otherwise similar house located outside the flood plain. This implies a marginal benefit per household for being located outside of the flood risk zone of about $14,172, on average.

We find strong evidence of price discounting for parcels of land in areas with higher risk. The magnitudes of the marginal effects are in line with estimates for other parts of the globe. However, it is not possible to conclude from this that the observed discounting is optimal, since the perceived risks might be different from the actual risks.

Nonetheless, our estimates should guide the decision to invest in future infrastructure. We have provided a simple and clear approach to estimate individuals' willingness to pay to reduce the "normal" risk of flooding.

7 Definition of variables

Flood risk: Dummy variable for flood hazard area (1 if the house is within the flood hazard area, 0 otherwise)

Fot (Total Occupancy Factor): It is the maximum surface that can be built as a proportion of the surface of the plot.

Width: Variable that considers the front measures of the lot in meters.

Width 2: Variable that considers the square of the front measure of the lot.

Length: Variable that considers the measure of the length of the lot in meters.

Length 2: Variable that considers the square of the length surface.

Gas: Dummy variable that takes on value 1 if the property has gas service and 0 otherwise.

Water: Binary variable that takes on value 1 if the property has running water service and 0 otherwise.

Sewer: Binary variable that takes on value 1 if the property has a connection with the sewage service and 0 otherwise.

Pavement: Variable dummy that takes value 1 if the property is located on a paved street and 0 otherwise.

Centenario Way and Belgrano Way are the most important roads and this is the reason why we include the following two dummy variables.

Centenario: Binary variable that takes on value 1 if the property is located on Centenario Way and 0 otherwise.

Belgrano: Binary variable that takes on value 1 if the property is located on Belgrano Way and 0 otherwise.

The borough division of La Plata District would leave few observations for each borough, making the regression analysis difficult. For this reason we decided to divide the district in only four zones: city center, south-east, south-west and north-west, with the aim of detecting the specific effects of each zone. We added 4 binary indicators; the urban center zone is the omitted one.

Distance: variable that indicates the distance of the lot to the city center (corner of 7 Avenue and 50 Street).

Distance2: distance square, this variable was included to test the existence of a nonlinear relationship between the distance and value of the lots.

8 Appendix

Figure 4:

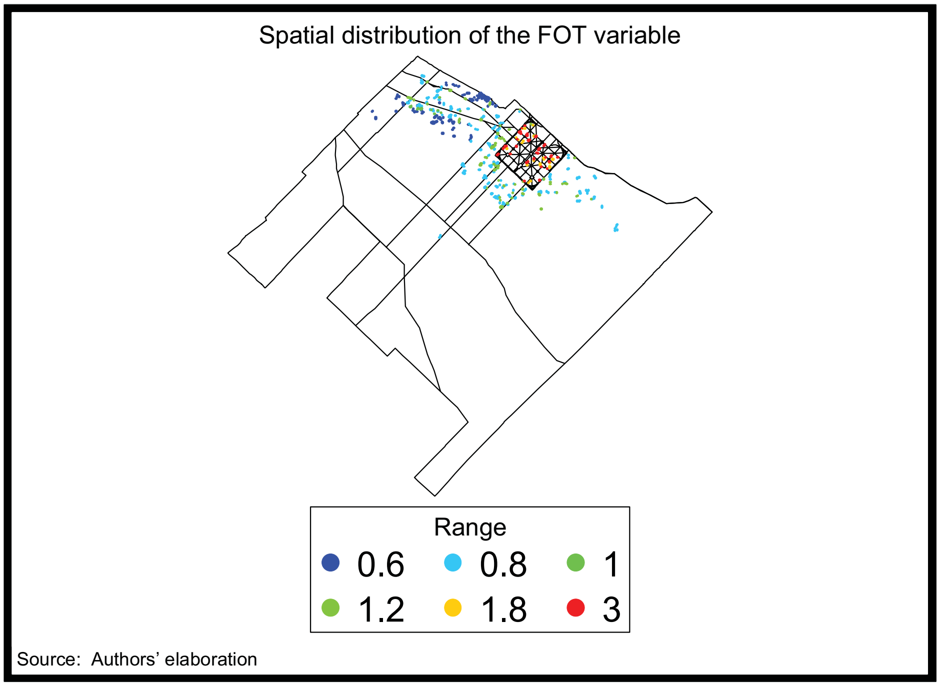


Figure 5:

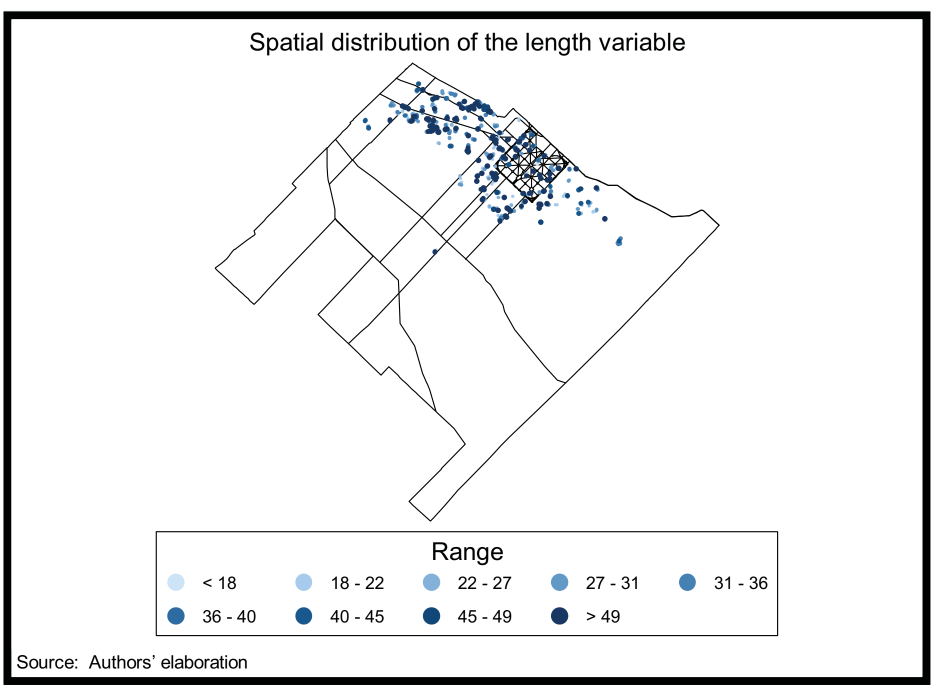


Figure 6:

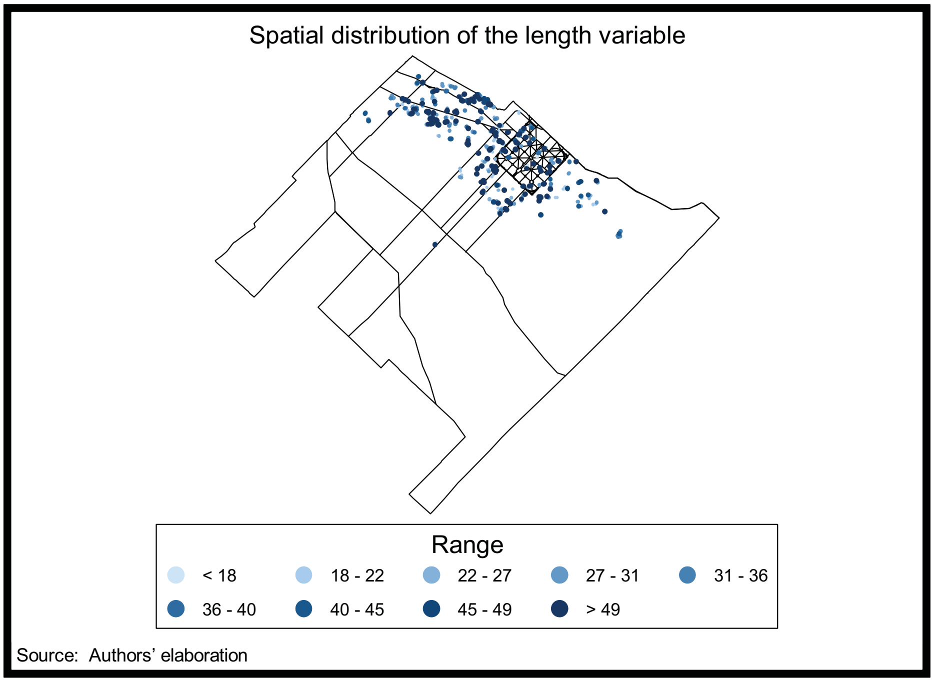


Figure 7:

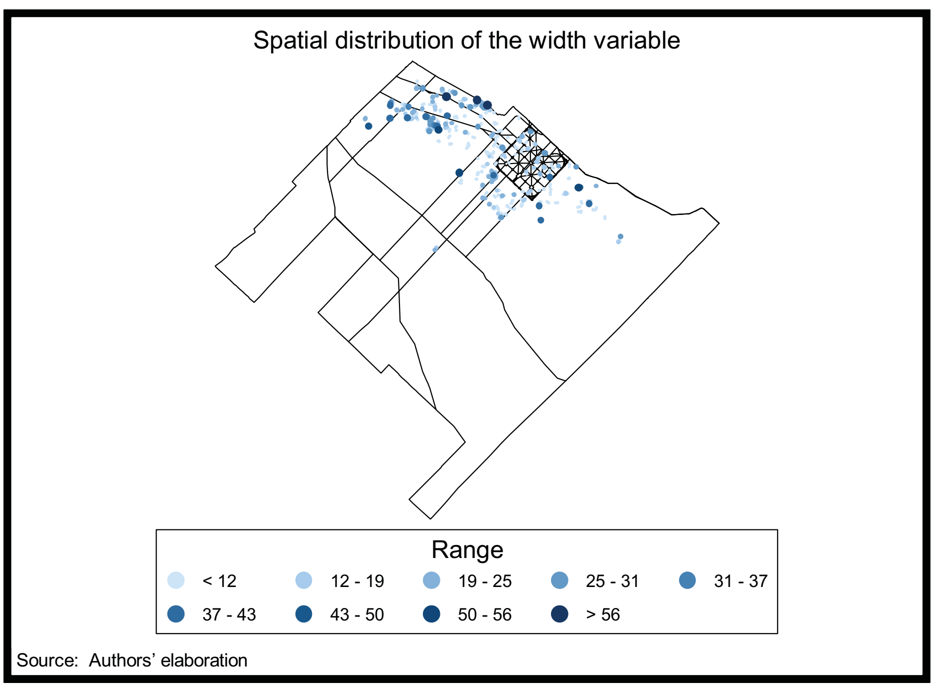


Figure 8:

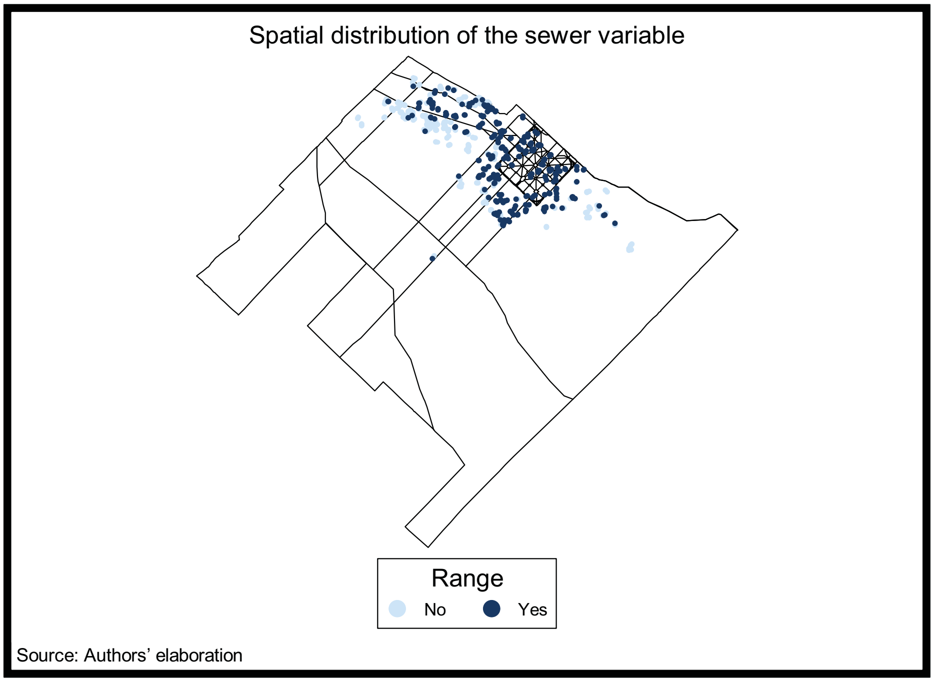


Figure 9:

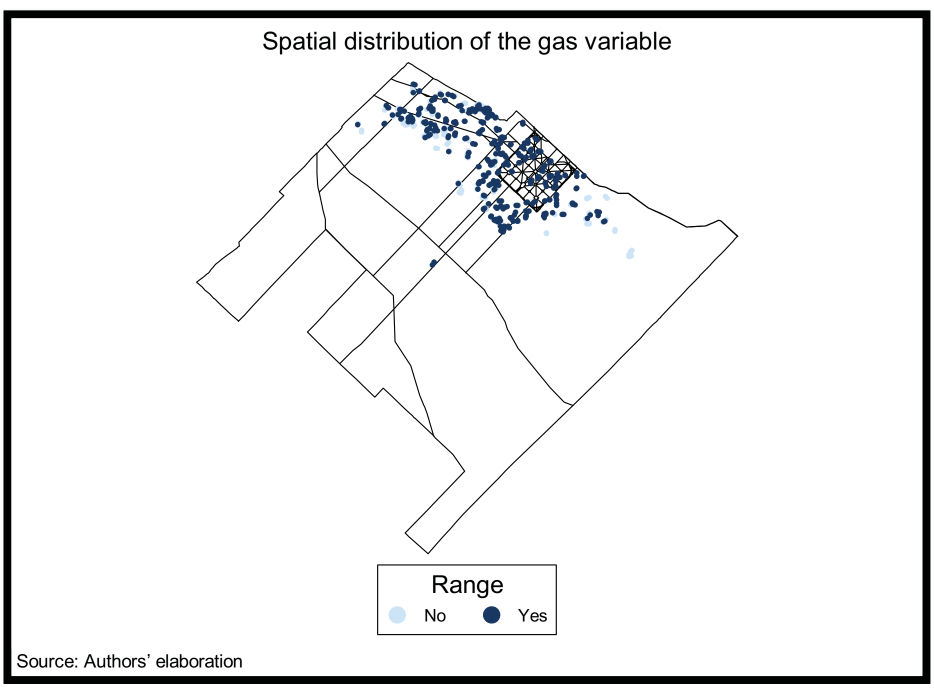


Figure 10:

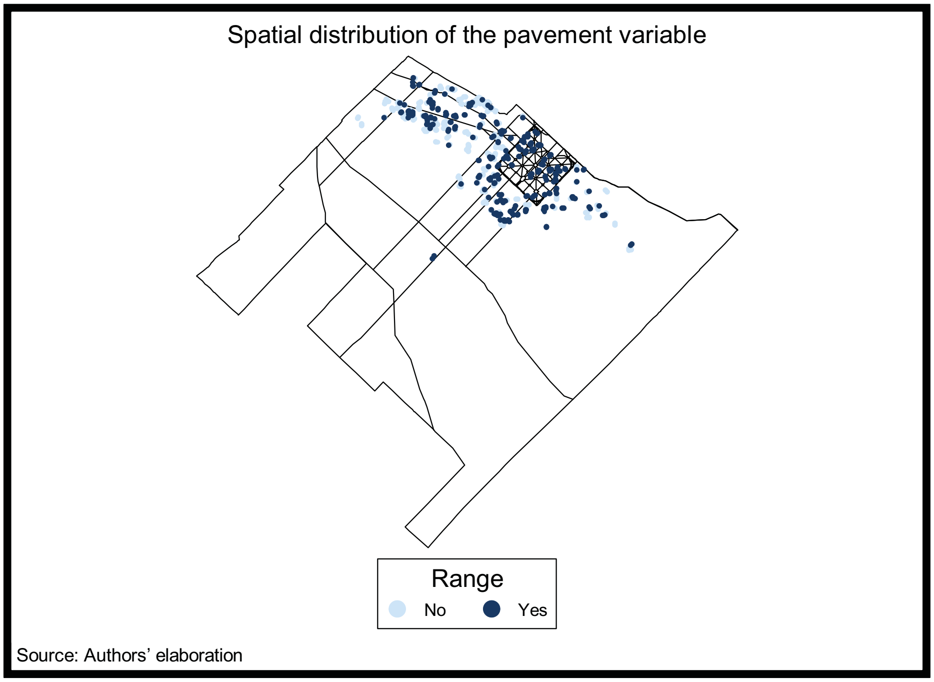
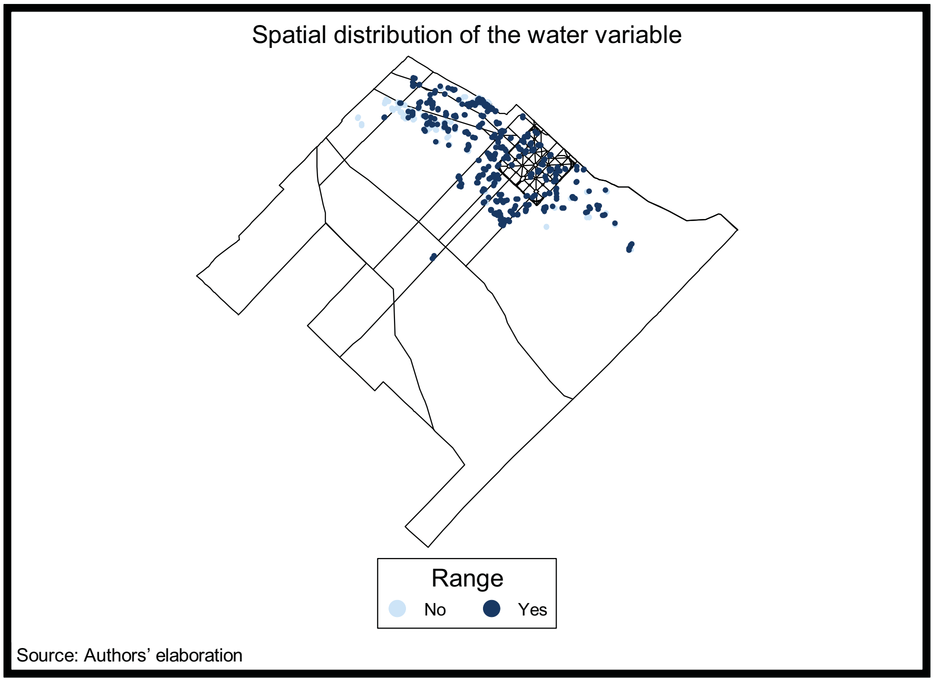


Figure 11:



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